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54 Ignition device for internal combustion engine.

57 An ignition device for an internal combustion engine having transistor means (301) for on-off controlling a primary current of an ignition coil (2) to produce a high voltage for spark ignition, comprises a reference voltage generator (301) for producing a temperature compensated reference voltage, a primary current detecting circuit (302) for producing a voltage corresponding to a primary current of the ignition coil (2), a comparator (314,315,316) for comparing said temperature compensated reference voltage with said voltage produced by said primary current detecting circuit (302) and a control circuit (308) responsive to an output of said comparator (314,315,316) to control a base voltage of said transistor means (301) to a predetermined constant value.

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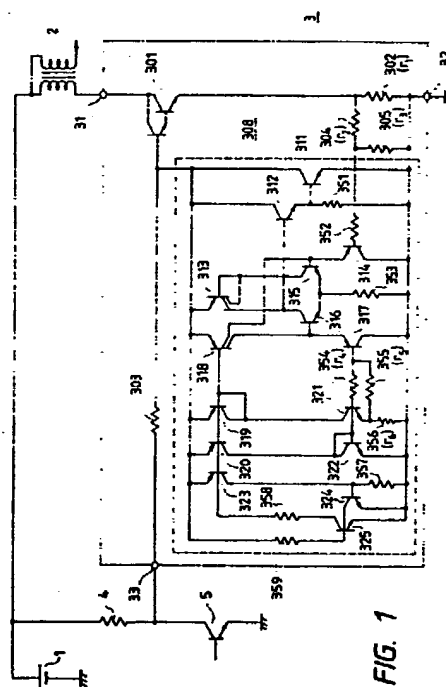


FIG. 1

## IGNITION DEVICE FOR INTERNAL COMBUSTION ENGINE

### BACKGROUND OF THE INVENTION

The present invention relates to an ignition device for an internal combustion engine and, particularly, to a device for limiting a primary current of an ignition coil thereof.

Fig. 3 shows an example of a conventional ignition device of this type, in which a reference numeral 1 depicts a power source, 2 an ignition coil, 3 an ignition device and 4 and 5 are a resistor and a transistor, respectively, constituting a circuit for producing a drive signal for the ignition device.

The ignition device 3 includes an output terminal 31 connected to the ignition coil 2, a grounding terminal 32 and an input terminal 33 connected to the circuit. When the transistor 5 of the circuit is on/off operated, a signal is supplied to the input terminal 33 of the ignition device 3 such that, upon a turn-off of the transistor 5, a current flows from the power source 1 through the resistor 4 and an internal resistance 303 of the ignition device to a base of a Darlington power transistor 301 to turn the latter on to thereby supply a primary current to the ignition coil 2.

A primary current detecting resistor 302 is provided between an emitter of the power transistor 301 and a ground point so that a voltage across the resistor 302 increases with increase of the primary current.

A transistor 307 has a base connected through a resistor 304 to the emitter of the power transistor 301, an emitter grounded and a collector connected to the base of the power transistor 301. Between the base and the emitter of the transistor 307, a circuit constituted with a resistor 305 and a transistor 306 is connected. When a voltage across the primary current detecting resistor 302 exceeds a turn-on voltage of the transistor 307, a current flows through the resistor 304 to the base of the transistor 307 and the resistor 305. The collector of the transistor 307 absorbs a portion of the base current of the power transistor 301 correspondingly to a degree of conduction of the transistor 307.

The primary current of the ignition coil is limited to a constant value when a balance condition determined by the base current of the power transistor 301, the voltage across the primary current detecting resistor 302, the base current of the transistor 307 and a current amplification factor of the transistor circuit composed of the power transistor 301 and the transistor 307 is satisfied.

The collector and the base of the transistor 306 are short-circuited so that it functions as a diode. That is, a temperature dependency of the base-emitter voltage of the transistor 307 is compensated

for by a temperature dependency of base-emitter voltage of the transistor 306 to thereby solving a temperature dependency problem of current limitation.

With such scheme as mentioned above, the primary current of the ignition coil is limited to a constant value which is just enough for ignition, allowing a use of a relatively small power transistor.

In the conventional device mentioned above, however, the constant primary current means that a current amount to be absorbed by the transistor 307 is constant, while the base current of the transistor 301 varies with a variation of the source voltage. That is, it is impossible to obtain a constant current limitation-value when the source voltage varies. For example, when the source voltage increases, the base current of the power transistor 301 increases correspondingly. In order to absorb a current increment by means of the transistor 307, it is necessary to increase the voltage across the primary current detecting resistor, i. e., to increase the primary current, requiring a large power transistor. On the contrary, when the source voltage decreases, the current limit value is lowered, causing an output of a secondary coil of the ignition coil to be lowered or a heat generation problem to occur.

It is usual that the transistor 306 provided for compensation of temperature dependency of the current limit value is not enough to cancel out a temperature dependent variation of a base-emitter voltage of the transistor 307 and that, due to the fact that the primary current detecting resistor 302 is of a metal having resistance varying with temperature, the current limit value is large at low temperature and small at high temperature.

### SUMMARY OF THE INVENTION

An object of the present invention is to provide an ignition device for an internal combustion engine which is capable of maintaining a current limit value constant for a variation of a source voltage and for a variation of temperature.

According to the present invention, the above object can be achieved by an ignition device which comprises a primary current detection circuit, a reference voltage generator having a temperature compensation function, a comparator and a control circuit. The reference voltage generator generates a constant reference voltage regardless of source voltage variation and has a temperature compensation function.

## BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is a circuit diagram of an ignition device for an internal combustion engine according to an embodiment of the present invention;

Fig. 2 shows waveforms at various points in the circuit shown in Fig. 1; and

Fig. 3 is a circuit diagram of a conventional ignition device.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In Fig. 1, a power source and an ignition are depicted by reference numerals 1 and 2, respectively, and an ignition device according to the present invention is depicted by a reference numeral 3. A transistor 5 is on-off controlled by an output signal of a control device which is not shown and has a collector connected to an input terminal 33 of the ignition device 3 and to a terminal of a resistor 4 whose the other terminal is connected to the power source 1. The transistor 5 supplies a drive signal for the ignition device 3. The latter has an output terminal 31, a grounding terminal 32 and an input terminal 33, as in the conventional device, and the output terminal 31 is connected to a primary terminal of the ignition coil 2.

The input terminal 33 of the ignition device 3 is connected through an input protection resistor 303 to a power transistor 301 and a constant current control circuit 308 and the output terminal 31 is connected to a collector of the power transistor 301. A primary current detecting resistor 302 having a resistance R1 for detecting a current of the primary coil of the ignition coil is connected between an emitter of the power transistor 301 and a grounding point 32, in parallel to a series connected resistors 304 and 305 having resistances R2 and R3, respectively. A junction of the resistors 304 and 305 is connected through a resistor 352 to one of input terminals of a comparator composed of transistors 313 to 318 and a resistor 353 of a constant current control circuit 308. The other input of the comparator is connected to an output of a reference voltage generator composed of transistors 319 to 322 and resistors 354, 355 and 356 having resistances R4, R5 and R6, respectively. A transistor 325 and resistors 358 and 359 constitute an actuation circuit for the reference voltage generator and the comparator and transistors 323 and 324 and a resistor 357 constitute a circuit for making the actuation circuit inoperative after the reference voltage generator and the comparator start to operate.

In operation, when the base voltage of the transistor 5 becomes "L" level as shown a

waveform a in Fig. 2, the latter is turned off and a current flows from the power source 1 through the resistors 4 and 303 to the base of the power transistor 301 to turn the latter on. A base voltage of the power transistor 301 at this time becomes equal to a base-emitter voltage thereof. Upon the conduction of the power transistor 301, a primary current flowing through the resistor 302 increases as shown by a waveform d in Fig. 2, upon which a voltage across the primary current detecting resistor 302 increases correspondingly. Therefore, the base voltage of the power transistor becomes a sum of the above mentioned base emitter voltage and the incremented voltage appeared on the resistor 302, which is shown by a waveform b in Fig. 2. It is known that the base-emitter voltage of the power transistor which is of Darlington type is in the order of 1.4 V. When a base voltage of the power transistor by which the latter is turned on is applied to the constant current control circuit 308, the transistor 325 is firstly turned on and absorbs a current from bases of the transistors 318 to 320 and 323 which constituting a current mirror circuit through the resistor 358 to thereby turn the transistors 318 to 320 and 328 of the current mirror circuit on. Then, when the transistors 322 and 321 are turned on by a collector current of the transistor 320, a voltage is produced across the resistor 356 the value of which depends upon an emitter current ratio between the transistors 322 and 321. A current flowing through the current mirror circuit is determined by the produced voltage across the resistor 356 and its resistance value R6. A voltage produced across the resistor 357 by a current supplied from the transistor 323 turns the transistor 324 on and transistor 325 of the actuation circuit off.

Since the amplification factor of transistor is large enough, an emitter current thereof is substantially equal to its collector current. When a sum of the resistances of the resistors 354 and 355 connected between the base-emitter of the transistor 321 is set large such that a current flowing from the resistor 355 to the resistor 356 is small compared with the emitter current of the transistor 321, a current flowing from the collector of the transistor 320 to the resistor 354 is small compared with the collector current of the transistor 320. Therefore, the emitter current of the transistor 321 becomes equal to the current flowing through the resistor 356 and the emitter current of the transistor 322 becomes equal to the collector current of the transistor 320.

The current I1 flowing through the resistor 356 is determined by the resistance R6 of the resistor 356 and a difference  $\Delta V_{BE}$  between the base-emitter voltage of the transistor 322 and the base-emitter voltage of the transistor 321. The current I1

and the difference  $\Delta V_{BE}$  are given by the following equations:

$$I_1 = (\Delta V_{BE})/R_6 \quad (1)$$

$$\Delta V_{BE} = (kT/q) \ln(ED322/ED321) \quad (2)$$

where  $k$  = Boltzman constant

$T$  = absolute temperature

$q$  = charge of electron

ED322 = emitter current density of transistor 322

ED321 = emitter current density of transistor 321

The ratio of current density between the transistors 321 and 322 in the equation (2) is given by the following equation since an error component thereof can be made negligible by setting the values  $R_4$  and  $R_5$  of the resistors 354 and 355 as mentioned previously.

$$(ED322)/(ED321) = (EA321)(EA320)/(EA322)(EA319) \quad (3)$$

where EA321: emitter area of transistor 321

EA320: emitter area of transistor 320

EA322: emitter area of transistor 322

EA319: emitter area of transistor 319

The reference voltage  $V_{ref}$  provided by the reference voltage generator circuit is supplied from a junction of the resistors 354 and 355 connected between the base and the emitter of the transistor 321 to a base of the transistor 317. The reference voltage  $V_{ref}$  is shown by a dotted waveform  $c$  in Fig. 2 and given by the following equation:

$$V_{ref} = \Delta V_{BE} + V_{BE}(321) (R_5/(R_4 + R_5)) \quad (4)$$

where  $V_{BE}(321)$ : base-emitter voltage of transistor 321.

The reference voltage generator circuit operates when the base voltage  $V_b(301)$  of the power transistor 301 satisfies the following condition:

$$V_b \geq V_{BE}(322) + V_{CE}(320) \quad (5)$$

or

$$V_b \geq \Delta V_{BE} + V_{CE}(321) + V_{BE}(319) \quad (6)$$

where  $V_{BE}(322)$ : base-emitter voltage of transistor 322

$V_{CE}(320)$ : collector-emitter saturation voltage

$V_{CE}(321)$ : collector-emitter saturation voltage

$V_{BE}(319)$ : base-emitter voltage of transistor 319

Since base-emitter voltage and collector emitter voltage of a transistor are 0.7V and 0.1V, respectively, and  $\Delta V_{BE} < 0.25$ , generally, it can be operated by the base voltage of the Darlington connected power transistor upon which the latter is turned on.

Since  $\Delta V_{BE}$  in the first term of the right side of the equation (4) has a positive temperature dependency while the temperature dependency of  $V_{BE}(321)$  is usually  $-2\text{mV}/^\circ\text{C}$ , the temperature dependency of the second term of the right side of the equation (4) can be negative by settings of the value  $R_4$  and  $R_5$  of the resistors 354 and 355, resulting in the reference voltage  $V_{ref}$  having arbitrarily settable temperature dependency as a total.

The base of the transistor 314 which constitutes an input of the comparator circuit is supplied with a voltage through the resistor 352 which is a fraction of the voltage generated across the primary current detecting resistor 302 and derived from the junction between the resistors 304 and 305. The base voltage  $V_b(314)$  of the transistor 314 is shown by a solid waveform  $c$  in Fig. 2 and given by the following equation:

$$V_b(314) = I_{pr} R_1 R_3 / (R_2 + R_3) \quad (7)$$

where  $I_{pr}$ : primary current of ignition coil

When  $V_b(314)$  defined by the equation (7) is going to exceed the  $V_{ref}$  given by the equation (4), a current is supplied from a junction between the collector of the transistor 316 and the collector of the transistor 313 which constitutes an output of the comparator to a base of the Darlington connected transistors 312 and 311 to make the latter conductive to thereby absorb the base current of the power transistor 301. Thus, a balance is established when  $V_{ref}$  shown by the equation (4) becomes equal to the  $V_b(314)$  shown by the equation (7), so that the primary current of the ignition coil can be limited to a constant current value.

The comparator circuit operates when the base voltage  $V_b$  of the power transistor 301 satisfies the following condition,

$$V_b \geq V_{ref} + V_{CE}(315) + V_{BE}(313) \quad (8)$$

where  $V_{CE}(315)$ : collector-emitter saturation voltage of transistor 315.

$V_{BE}(313)$ : base-emitter voltage of transistor 313.

Therefore, it can be operated reliably upon the base voltage of the power transistor upon which the latter is turned on.

The operating voltage of the Darlington transistors 312 and 311 is

$$V_{BE}(311) + V_{BE}(312) + V_{CE}(313) \quad (9)$$

where  $V_{BE}(311)$ : base-emitter voltage of transistor 311

$V_{BE}(312)$ : base-emitter voltage of transistor 312

$V_{CE}(313)$ : collector-emitter saturation voltage of transistor 313.

This is substantially the same as the base-emitter voltage of the Darlington power transistor when turned on. Since, however, the transistors 311 and 312 are to be operated only when the primary current is increased, the base voltage of the power transistor is increased as shown by the waveform  $b$  in Fig. 2 to a value much higher than the voltage defined by the equation (9) under such condition. Therefore, the constant current control circuit 308 which is operated by the base voltage of the Darlington power transistor 301 can regulate the current limit value to a constant value regardless of source voltage variation and temperature variation.

As described hereinbefore, according to the present invention by which it is possible to limit the primary current of the ignition coil to a constant

value regardless of variations of source voltage and temperature, low rated transistors can be used with high reliability.

#### Claims

1. An ignition device for an internal combustion engine having transistor means for on-off controlling a primary current of an ignition coil to produce a high voltage for spark ignition, comprising a reference voltage generator for producing a temperature compensated reference voltage, a primary current detecting circuit for producing a voltage corresponding to a primary current of the ignition coil, a comparator for comparing said temperature compensated reference voltage with said voltage produced by said primary current detecting circuit and a control circuit responsive to an output of said comparator to control a base voltage of said transistor means to a predetermined constant value.

2. The ignition device as claimed in claim 1, further comprising an actuation circuit for actuating said comparator only when the primary current of the ignition coil increases above a predetermined value.

3. The ignition device as claimed in claim 1 or 2, wherein said reference voltage generator comprises a current mirror circuit and a pair of transistor circuits.

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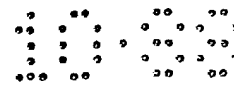
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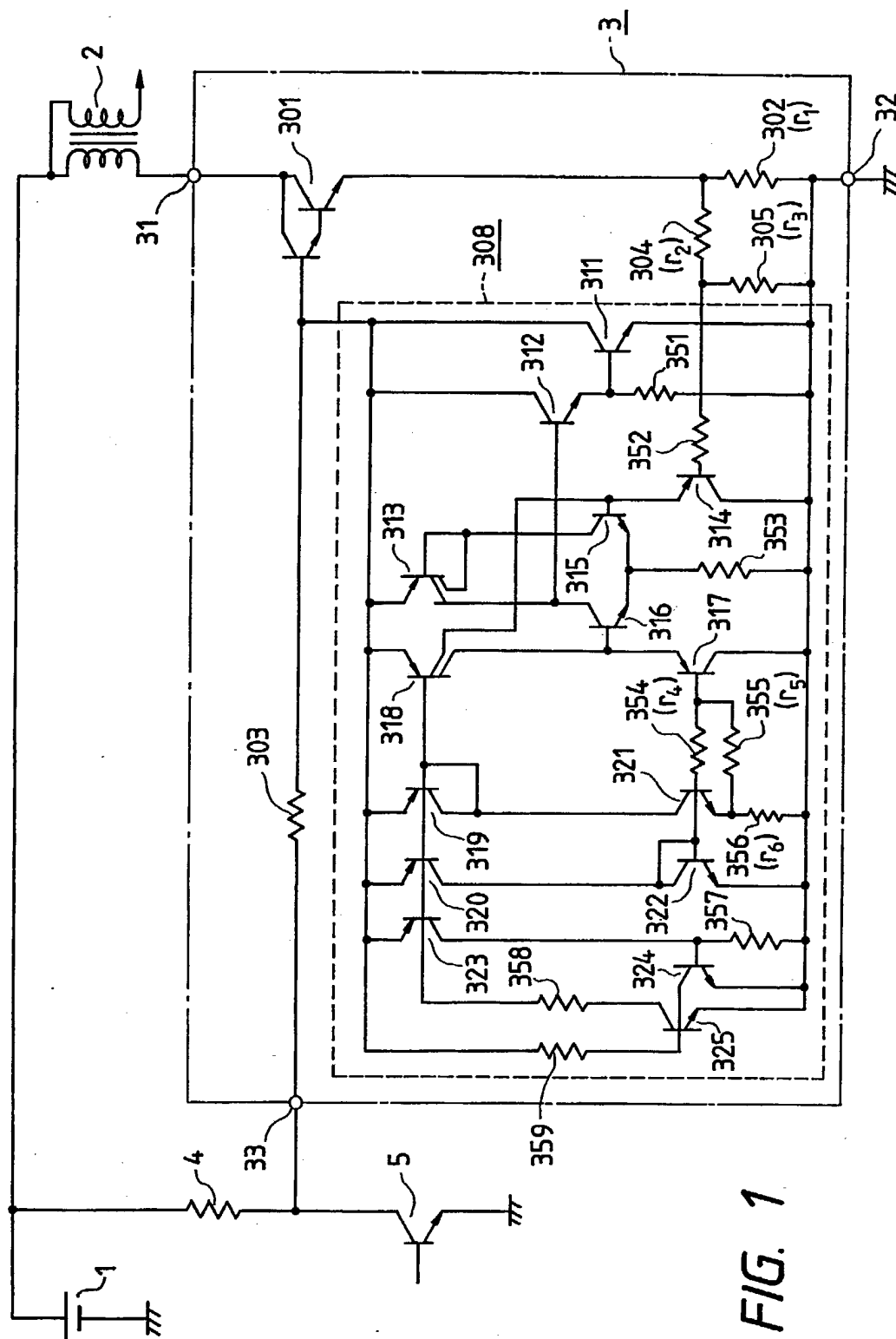


FIG. 1

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FIG. 2

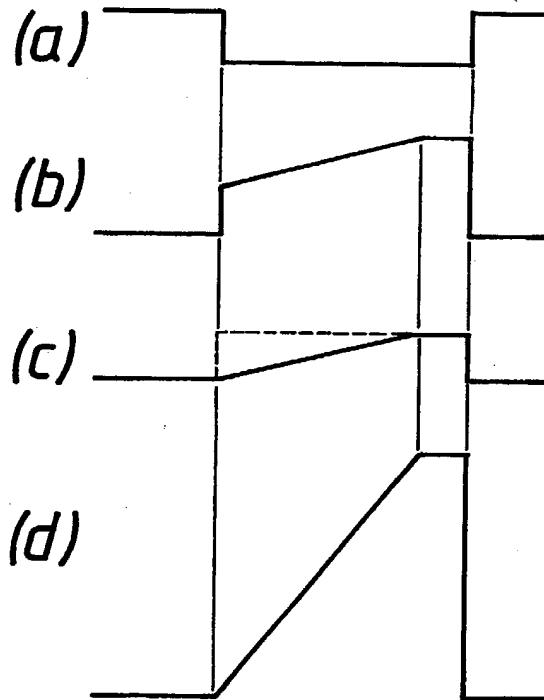
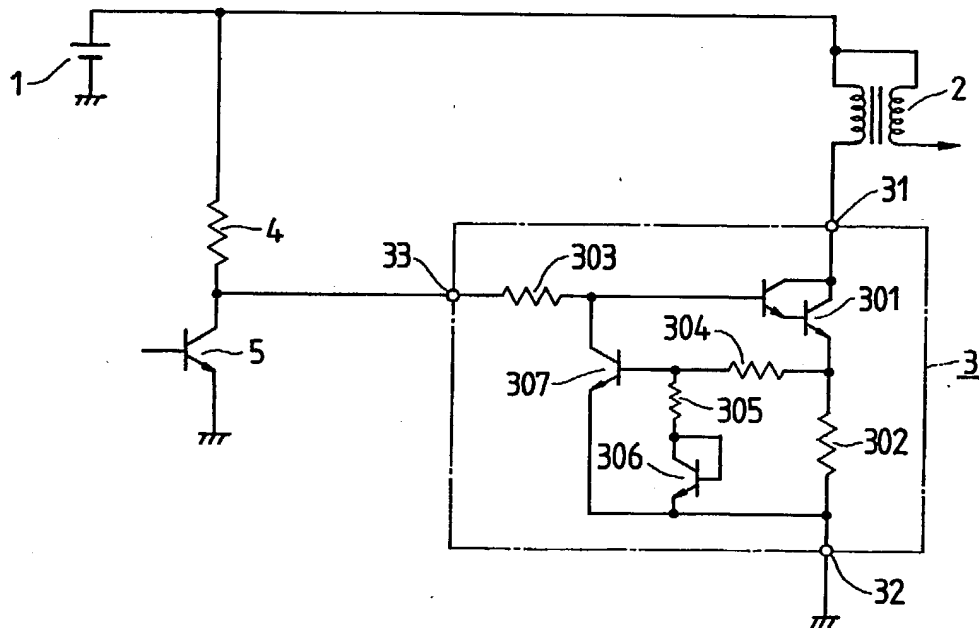


FIG. 3





DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. CL 4)
Y	US-A-3 933 141 (P. GUNDERSON) * Front-page *	1	F 02 P 3/05
Y	US-A-4 509 494 (NISHITOBA et al.) * Front-page; figures 1,2; column 3, line 14 - column 6, line 40 *	1	
A	---	2,3	
A	US-A-3 901 205 (H.J. BRUNGSBERG) * Front-page; figures; column 2, lines 56-68 *	1,2	
A	GB-A-2 073 314 (R. BOSCH)		
A	US-A-3 902 471 (BRUNGSBERG)		
			TECHNICAL FIELDS SEARCHED (Int. CL 4)
			F 02 P
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 05-04-1989	Examiner LEROY C.P.
<b>CATEGORY OF CITED DOCUMENTS</b> X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ..... & : member of the same patent family, corresponding document			



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combustion engine.

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INVENTOR-INFORMATION:

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ABSTRACT:

An ignition device for an internal combustion engine having transistor means (301) for on-off controlling a primary current of an ignition coil (2) to produce a high voltage for spark ignition, comprises a reference voltage generator (301) for producing a temperature compensated reference voltage, a primary current detecting circuit (302) for producing a voltage corresponding to a primary current of the ignition coil (2), a comparator (314,315,316) for comparing said temperature compensated reference voltage with said voltage produced by said primary current detecting circuit (302) and a control circuit (308) responsive to an output of said comparator (314,315,316) to control a base voltage of said transistor means (301) to a predetermined constant value.

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Abstract Text - FPAR (1):

An ignition device for an internal combustion engine having transistor means (301) for on-off controlling a primary current of an ignition coil (2) to produce a high voltage for spark ignition, comprises a reference voltage generator (301) for producing a temperature compensated reference voltage, a primary current detecting circuit (302) for producing a voltage corresponding to a primary current of the ignition coil (2), a comparator (314,315,316) for comparing said temperature compensated reference voltage with said voltage produced by said primary current detecting circuit (302) and a control circuit (308) responsive to an output of said comparator (314,315,316) to control a base voltage of said transistor means (301) to a predetermined constant value.